

IMAGE WATERMARKING SCHEME USING SVD

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ABSTRACT

Several watermarking schemes have been widely used to solve the copyright protection problems of the image. In this paper, to improve the robustness and protection, two watermarking schemes are presented. First watermarking scheme is single level watermarking in which we embed the watermark into cover image in RGB space. Second watermarking scheme is dual watermarking scheme in which two watermarks are embedded in the host image. For both watermarking schemes, we used Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) Mathematical tools. The combination of DWT and SVD are used to achieve high robustness against different types of attacks like cropping, resizing, rotation etc.

Keywords: Discrete Wavelet Transform (DWT), MSE, PSNR, Singular Value Decomposition (SVD), Watermarking.

I. INTRODUCTION

Watermarking is a technique for inserting information (the watermark) into an image, which can be later extracted or detected for variety of purposes [2, 10]. Watermarking is an important mechanism applied to various objects like bills, papers, garment labels, product packing. Watermarking serve for many purposes like copyright protection, broadcast monitoring and data authentication [7, 8, 10]. There are many different watermarking algorithms have been proposed in the literature. Mainly, there are two categories of watermarking technique, spatial domain and transform or frequency domain [7, 8, 10, and 11]. Watermarking in transform domain is more robust and secure to different attacks as compared to spatial domain [10]. The combination of DWT and SVD are used to achieve high robustness against attacks like compression, cropping, rotation, resizing etc [8, 10, and 11].

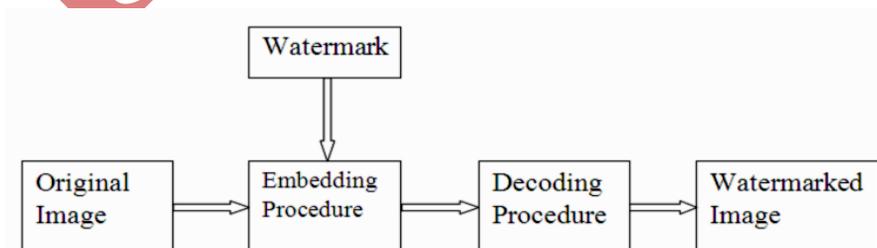


Figure 1: An overview of Watermarking Procedure

The procedure of embedding and retrieval of watermark from watermarked image is shown in fig 1. Take the original image on which watermark should apply and then use some appropriate watermark embedding technique using which watermark can safely apply on original image. After that the decoding procedure at the other end, in which using some decoding algorithm on that image the watermarked can easily obtain. Meanwhile some attack may apply on your watermarked image by some unknown party. So choose such watermark embedding technique which is robust to such attacks.

SVD is a numerical technique used to decompose a matrix into several component matrices, exposing many of the useful properties of the original matrix [11]. In this paper, we have presented two watermarking schemes; first watermarking scheme is single level watermarking in which we embed the watermark into cover image in RGB space. Second watermarking scheme is dual watermarking scheme in which two watermarks are embedded in the host image. First watermark is primary watermark and second is secondary watermark. The SVD and DWT mathematical tools are used to embed watermark in the cover image. SVD is one of the most important numeric analysis techniques with various applications which include watermarking.

II. DISCRETE WAVELET TRANSFORM

Discrete wavelet transform is a multi-resolution decomposition of a signal. The low pass filter applied along a certain direction extracts the low frequency (approximation) coefficients of a signal. On the other hand, the high pass filter extracts the high frequency (detail) coefficients of a signal. The two-dimensional wavelet transform that we describe can be seen as a one-dimensional wavelet transforms along the x and y axes. Mathematically the wavelet transform is convolution operation, which is equivalent to pass the pixel values of an image through a lowpass and highpass filters. The image is represented by two dimensional signal functions; wavelet transform decomposes the image into four frequency bands, namely, the LL1, HL1, LH1 and HH1 bands. H and L denote the highpass and lowpass filters respectively. The approximated image LL is obtained by lowpass filtering in both row and column directions. The detailed images, LH, HL and HH contains the high frequency components. To obtain the next coarse level of wavelet coefficients, the sub \hat{A} band LL1 alone is further decomposed and critically sampled. Similarly LL2 will be used to obtain further decomposition. By decomposing the approximated image at each level into four sub-images forms the pyramidal image tree. This results in two-level wavelet decomposition of image, the two-level DWT decomposition is shown in Fig. 2

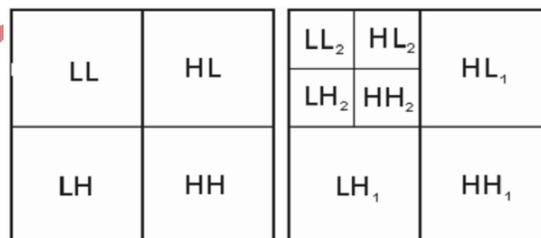


Figure 2: Scale and 2-Scale2 Dimensional Discrete Wavelet Transform.

The wavelet transform of image gives four frequency sub band coefficients and each sub band is resistant to different types of attacks.

III. SINGULAR VALUE DECOMPOSITION (SVD)

SVD is the most powerful numeric analysis technique with numerous applications including watermarking. SVD is a special matrix transform. The singular value of image can capture the intrinsic characteristics rather than the visual effects, and its excellent stability prevents big changes of the singular value due to small image disturbance. All these features make SVD widely used in digital watermarking.

In linear algebra, the singular value decomposition (SVD) is factorization of a real or complex matrix, with many useful applications in signal processing and statistics. To solve the many mathematical problems, a linear algebra technique used called as Singular value decomposition. Any image can be considered as a square matrix without loss of generality. So SVD technique can be applied to any kind of images. The SVD belongs to orthogonal transform which decompose the given matrix into three matrices of same size. To decompose the matrix using SVD technique it need not be a square matrix. Let us denote the image as matrix A. The SVD decomposition of matrix A is given using equation,

If A is any N x N matrix, it is possible to find a decomposition of the form,

$$A=USV^T \dots\dots\dots (1)$$

Where U is an mxm real or complex unitary matrix and V^T (the conjugate transpose of V) is an nxn real or complex unitary matrix such that,

$$\begin{aligned} U * U^T &= I \\ V * V^T &= I \dots\dots\dots (2) \end{aligned}$$

Where, I represents an Identity matrix and S is the diagonal matrix of order mxn having elements S_i ($i=1, 2, 3, n$). The singular values of A are represented by the diagonal elements of S. The columns of U matrix are known as the left singular values of A, and the columns of V are known as the right singular values of A. Such a factorization is called the singular value decomposition of A.

IV. SINGLE LEVEL WATERMARKING

4.1 Watermark Embedding

This watermarking embeds the monochrome watermark image into color cover image. The color image consists of three channels as Red (R), Green (G) and Blue (B). From these three channels, B channel is used for embedding.

4.1.1. Watermark Embedding Algorithm

The Watermark Embedding Algorithm is given as:-

Input-

The color image I and monochrome watermark W.

Output-

The watermarked color image I'.

1. Separate Red (R), Green (G), and Blue (B) channels from the color image I.
2. Apply one-level DWT on B channel to produce the subband coefficients {LL, LH, HL, and HH}.
3. Apply SVD on each subband coefficients to get singular values.
4. Apply inverse SVD using singular values to get modified subbands.
5. Apply inverse DWT on modified subband coefficients to produce the watermarked B channel.
6. Transform the R, G and watermarked B channels onto color image.

4.1.2 Watermark Extraction Algorithm

The extraction of watermark is exactly opposite to the watermark embedding process. This is applied to various test images. The Watermark Extraction Algorithm is given as:-

Input-

The cover color image I, watermarked cover image I' and watermark W.

Output-

1. The monochrome watermark W
2. Separate R, G and B channels from the color image I.
3. Separate R', G' and B' channels from the watermarked image I'.
4. Apply SVD on watermark to get the singular values.
5. Apply one-level DWT on Band B' channel to produce the subband coefficients {LL, LH, HL, HH} and {LL', LH', HL', HH'} .
6. Apply SVD on all the subband coefficients B and B' to produce singular values {LL, LH, HL, and HH}.
7. Construct the four watermark images using singular Vectors.
8. Extracted Watermark vectors contain non binary value since the watermark is a monochrome image this vector is optimized by using root mean square value.

In this watermarking scheme, color image of size 512 x 512 and monochrome watermark image of size 128 x 128 is used.

V. DUAL WATERMARKING SCHEME

In this watermarking scheme, two watermarks are embedded in the host image. The first watermark is called primary watermark and the second watermark is called secondary watermark. This watermarking scheme is for gray scale digital images. The secondary watermark is embedded into primary watermark and the resultant watermark image is used as watermark for the host image. Secondary watermark is easy to detect but primary is harder sometimes.

5.1. Watermark Embedding

5.1.1 Embedding Secondary Watermark

1. Perform 1-level wavelet transform on the primary watermark.
2. Perform SVD transform on secondary watermark.
3. Perform SVD transform on approximation and all the detail parts.
4. Modify the singular values of approximation and all the detail parts with the singular values of the secondary watermark.
5. Obtain modified approximation and all the detail parts.
6. Perform 1-level inverse DWT to get the watermarked primary watermark.

5.1.2 Embedding Primary Watermark

The resultant watermarked primary watermark image is the watermark for the host image and it is used for the following embedding algorithm.

1. Perform 1-level wavelet transform on the host image.
2. The details and approximation sub-images of the host image is segmented into non overlapping rectangles using ZIG-ZAG sequence.
3. Perform SVD transform on new primary watermark.
4. Perform SVD transform on all non overlapping rectangles.
5. Modify the singular values of all non overlapping rectangles with the singular values of the new primary watermark.
6. Obtain all modifies non overlapping rectangles.
7. After embedding, reconstruct approximation and all the detail parts using De-ZIG-ZAG sequence.
8. Perform 1-level inverse discrete wavelet transform to get watermarked image.

5.2 Watermark Extraction

For watermark extraction from watermarked image, both watermark and host images are needed. The extraction process is as follows.

5.2.1 Extracting Primary Watermark

1. Perform 1-level wavelet transform on the host as well as watermarked image.
2. The detail and approximation sub-images of the host as well as watermarked image is segmented into non-overlapping rectangles using ZIG-ZAG sequence.
3. Perform SVD transform on all non-overlapping rectangles of both the images.
4. Extract singular values of primary watermark from all non-overlapping rectangles.
5. Obtain all estimate of primary watermark.
6. Select the primary watermark estimate as detected watermark which has the greatest correlation coefficient.

5.2.2 Extracting Secondary Watermark

1. In this section, we extract secondary watermark from the image which we got from previous section.
2. Perform 1-level wavelet transform on the primary watermark.
3. Perform SVD transform on approximation and all the detail parts of both images.
4. Extract singular values of secondary watermark from approximation and all detail parts.
5. Obtain all estimate of secondary watermark.
6. After detecting all estimate of secondary watermark, sum up all these.

In this watermarking scheme, we have taken gray scale Lena image of size 512 X 512 and for primary and secondary watermark we have taken 8 bit gray scale image and logo image of sizes 128 X 128 and 64 X 64 respectively.

To investigate the robustness of the watermarking scheme, the watermarked image is attacked by resize, cropping, rotate, and salt & pepper noise, Poisson noise, median filter etc. After these attacks on the watermarked image, we compare the extracted watermarks with the original one. The watermarked image quality is measured using peak signal to noise ratio (PSNR) and mean square error (MSE). Lower the value of MSE lower the error and better picture quality. Larger the PSNR value, the better the image quality. MSE and PSNR can be calculated as,

$$MSE = \frac{1}{MN} \sum_{y=1}^M \sum_{x=1}^N [I(x,y) - I'(x,y)]^2 \dots\dots\dots (3)$$

$$PSNR = 10 \log_{10} \left(\frac{255^2}{MSE} \right) \dots\dots\dots (4)$$

Where $I(x,y)$ is the original image and $I'(x,y)$ is the decomposed image and M,N are the dimension of the image.

VI. RESULTS

6.1. Results for Single level watermarking



Watermark B plane Reconstructed Image



Figure3: Watermark Embedding.



Figure4: Extracted logos from different subbands. a) Extracted watermark from LL. b) Extracted watermark from LH. c) Extracted watermark from HL. d) Extracted watermark from HH.

6.2. Results for dual watermarking

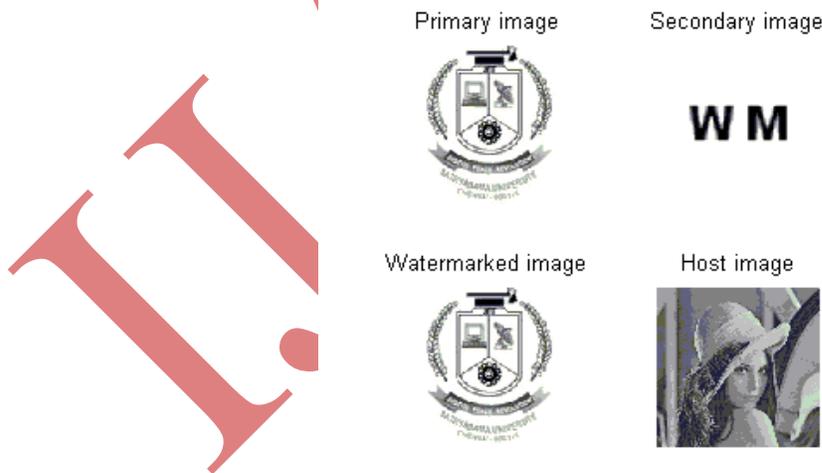


Figure 5. Watermark Embedding

Final Watermarked image Primary Extracted image



secondary Extracted image

WM

Figure 6: Watermark Extraction

In Fig. 5 and 6, Original, Watermarked Images and Extracted watermarks are shown

Name of Attacks	Single level watermarking	Dual Watermarking
Salt and Pepper Noise	356.719	1.7066
Poisson Noise	107.3963	1.7064
Cropping	2.6287	4.0548
Resize	29.7034	0.3288
Rotate	6.3877	1.0255
Median Filter	32.1060	18.7566

Table 1: MSE for single level watermarking and dual watermarking schemes after applying different types of attacks.

Name of Attacks	Single level watermarking	Dual Watermarking
Salt and Pepper Noise	22.6076	5.8094
Poisson Noise	27.8209	5.8101
Cropping	13.9333	12.0511
Resize	33.4027	52.9611
Rotate	10.0774	8.0213
Median Filter	33.0649	35.3993

Table 2: PSNR for single level watermarking and dual watermarking schemes after applying different types of attacks.

Name of Attacks	Single level watermarking	Dual Watermarking
Salt and Pepper Noise	0.8683	-0.0013
Poisson Noise	0.9562	-0.0021
Cropping	-0.1467	0.1411
Resize	0.9872	1
Rotate	0.1413	0.0365
Median Filter	0.9859	0.9959

Table 3: Correlation coefficient between host and watermarked image for single level watermarking and dual watermarking schemes after applying different types of attacks.

VII. CONCLUSION

This watermarking scheme using SVD –DWT increases the robustness against different types of attacks. In both watermarking schemes, dual watermarking is more robust against different types of attacks than single level watermarking. Dual watermarking improves the protection of the data.

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